UCL ENERGY INSTITUTE

Barriers to uptake of energy efficient operational measures

Survey Report

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Low Carbon Shipping – A systems Approach

International shipping accounted for 2% to 4% of global CO2 emissions in 2009 and it is estimated that this share will grow by 150 -250% (compared to emissions in 2007) by 2050, if the industry is left uncontrolled and in absence of policies (IMO, 2009). To meet the energy and carbon challenges, the shipping industry needs to develop a strategy incorporating both technological and operational measures such that objectives are met at low or least cost, and which provide an economically stable and environmentally sound service in a context of uncertainties such as volatile fuel costs and availabilities (Smith et al, 2009).

The 'Low Carbon Shipping – A systems Approach' is the result of a call by the Engineering and Physical Sciences Research Council (EPSRC), which recognised the need for further research in this subject. Low Carbon Shipping is made up of a consortium of five UK universities; University College London, Newcastle University, University of Strathclyde, University of Hull and University of Plymouth and a number of industry partners. The project started in January 2010 and it is majority funded by the RCUK energy (UK government research funding) programme (£1.7m over 3 years), but also supported financially and in-kind by a number of industry partners including Lloyds Register, Rolls Royce, Shell and BMT. The work is divided into 6 work packages, from which outputs are collated to provide inputs into the holistic analysis:

1. Modelling the global shipping system
2. Technologies for low carbon shipping
3. Shipping, ports and logistics
4. Shipping economics and life cycle costs
5. Regulation, policy and barriers
6. Operation for low carbon shipping

One of the high level aims of the EPSRC was to assess implementation barriers to low carbon shipping. Work package five thus has mainly focussed on answering the following questions:

- What operational measures are available to shipping to improve energy efficiency?
- Are these measures being currently implemented?
- If not, why are they not being implemented?
- What is the relative importance of each type of barrier for each operational measure, especially speed reduction?
- What is the relative importance of the differing types of charter as a barrier to adoption of energy efficient operational measures and how does this vary between sectors?

Contents

Executive summary

As part of the PhD research a survey was conducted to identify which energy efficient/fuel saving operational measures are currently being implemented and those that are not being implemented by the shipping industry and the reasons for doing so. Nearly 150 responses were received and the survey provided a general overview of the uptake of measures and shed light on why some measures were not undertaken or seemed unattractive for investment. Central to the survey was the theory of market barriers and failures (e.g. risk, access to capital, split incentives) that contribute to the efficiency gap.

Key findings:

- Fuel consumption monitoring, general speed reduction and weather routing were most frequently cited as measures having the highest potential for fuel savings and CO_2 reduction.
- The above measures that were believed to be of highest potential have actual implementation rate of around 65-85% and on average across all the measures the implementation rate was around 50%.
- Respondents cited that the above had high potential because savings from the investment could be fully recouped, the operations were under direct control and that there were no additional costs involved.
- The most pertinent barrier across all measures that were not selected (i.e. seemed to have lower fuel saving potential) were lack of reliable information on cost and savings, difficultly in implementing under some types of charter, lack of direct control over operations & materiality of savings.
- The main barriers to speed related measures were difficulty in implementing under different types of charter, charterparty clauses, unsuitable to the trade/route of operation and constant delays in ports using first come first serve allocation of berths.
- The size of the company was almost perfectly negatively correlated to the number of respondents citing lack of reliable information on cost and savings. Small companies more frequently cited this as a barrier in comparison to large companies.
- The second and third most cited barrier; difficult to implement the measures under some types of charter followed by lack of direct control over operations, were a result of the different types of charter suggesting that chartering arrangements/ratios (that lead to split incentives) may be barrier towards uptake of operational measures.

Introduction

A common method of presenting analysis of the order in which options might be adopted and the likelihood of investment, particularly for policy work, is the Marginal Abatement Cost Curve (MACC), examples of which for shipping can be found in Faber et al. 2009, Bauhaug et al. 2009, IMO 2010, Det Norske Veritas 2009. The focus of the survey was on operational measures and specifically voyage related measures because not only do they require comparably smaller investment in contrast to other measures but almost all of these are shown to be at a negative cost by the aforementioned. Furthermore such operational/voyage related measures can lead to instant reductions in CO_2 emissions since they are applicable to existing and future fleet (Rehmatulla & Smith, 2012).

Besides the inherent shortcomings in MACC analysis (Kesicki 2010), for shipping it is commonly undertaken with an incomplete representation of costs and little representation of risk (beyond the investment rate of return). The result from the above referenced analyses has so far been the identification of substantial (e.g. up to 30%) unrealised abatement potential using options that often appear to be cost-negative at current fuel prices. This contradicts the logic that a competitive industry with a dominant energy cost should be overlooking opportunities to increase efficiency at a profit. Possible explanations are that either:

- Models for analysis are inadequate for representing costs/benefits of low carbon and energy efficiency investment or the data used are incorrect (i.e. hidden costs, inadequate representation of risk); or
- Other implementation barriers/failures exist which are obstructing the shipping industry' s implementation of low carbon such as informational problems, split incentives, access to and cost of capital (Rehmatulla & Smith, 2012).

It is possible to gain some insight into the relative significance of each of these explanations, by looking at how this work has been discussed by others both for shipping and other industries. AEA (2008), Faber et al (2009), IMarEST (2010), Faber et al (2011), Rehmatulla (2011), Heisman & Tomkins (2011) have discussed barriers to implementation of abatement options in shipping. . A brief description and overview of the barriers literature is provided in the annex to this report.

Survey methodology

The purpose of the survey was to assess the uptake of such cost-effective/cost negative and energy efficient operational measures within the shipping industry. The survey was able to provide a general indication of what measures are implemented in each of the shipping sectors and shed light on why some measures were not undertaken or seemed unattractive for investment. Having gained approval by UCL and UK Data Protection, data collection through the online survey ran from November 2011 to April 2012.

The unit of analysis/target population were global shipping companies with more than 5 ships which consisted of shipowners, ship owner-operators, ship management company & shipping division major charterers/cargo owners in the wetbulk, drybulk & container sectors only. These were recruited from Clarksons Shipping Information Network (SIN) database of shipowners. It is believed that this is the most comprehensive list of the target population. However upon comparison with other online databases such as World Shipping Directory slight undercoverage of companies was noted. Effort was made to merge the frames to cover accurately the target population. A stratified sampling approach was taken so as to represent the different variables of interest to the survey. A company with 90% of its fleet belonging to a sector would be placed in the respective sector category and when the fleet composition falls below 90% for one sector, the company is placed under the mixed sector. Below is schematic showing the stratified sampling frame design.

Sector	Size	Company	Parent/subsidiary/division	Region	DWT	No. Of ships
Wetbulk	Large					
	Medium					
Drybulk	Large					
	Medium					
Container	Large					
	Medium					
Mixed	Large					
	Medium					

Notes/definitions: Large companies = 50 ships +, Medium companies = 10 – 49 ships, Small companies = 5 – 9 ships

Upon refining and stratifying the frame (as shown above) had just around 600 large and medium companies (target population) and it was decided to take a census approach i.e. contact every company with 10 ships or more. Four to five points of contact were made with each company starting with pre-notification email to each company' s general email, followed by a call to speak to the technical/operations senior personnel, follow up email to the relevant person, reminder call to these persons and concluding with a final reminder email. For the small companies consisting of approximately 1000 companies it was decided to take a random sample. The total number of companies that responded was 149 which consisted of 97 almost complete (90% item response) responses and 52 partially completed responses making the response rate for large and medium companies just over 15% (80% of sample required) and 50% of sample required for small companies. In order to be representative and to make generalisations i.e. reach statistically overall significant results with a confidence level of 90% and margin of error interval of +/-15% or +/-20% each stratum required the following number responses:

Sector	Size	Population	+/- 15% Sample required	+/- 20% Sample required	Sample achieved
Wetbulk	Large	27	15	11	6
	Medium	141	25	16	12
Drybulk	Large	18	12	9	3
	Medium	141	25	16	13
Container	Large	24	14	11	1
	Medium	57	20	14	4
Mixed	Large	49	19	13	0
	Medium	143	25	16	16
		600	155	106	55
All	Small	≈ 1000	30	17	24
Total		1600	185	123	79

The above figures for the sample required are directly from the responses of the participants which in comparison to the sampling frame from Clarksons SIN were slightly different. For example the frame showed that only 2 large wetbulk companies had responded to the survey and 21 medium sized wetbulk companies responded. Due to the level of non response there may be a presence of systematic biases (i.e. those who responded are significantly unlike those who failed to). However because of scarcity of information on this subject area, even such low response rate may be able to provide useful information, hence the decision to publish the results as is, without any weightings and inferences to the population.

For those who responded, the item non response along the questionnaire is depicted below in figure 1. From the beginning (q1) to end (q17) the responses to the questions are halved.

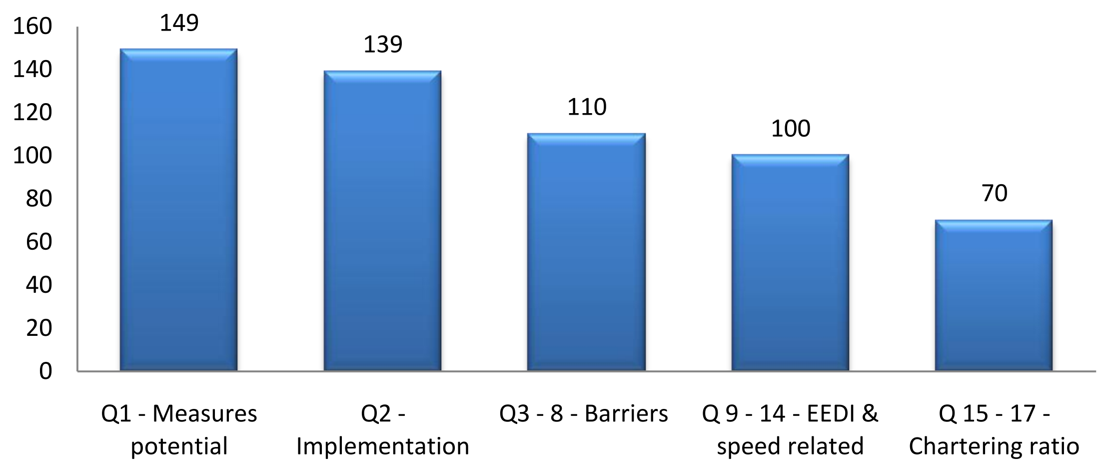


Figure 1: Response rates per question

In order to make the sampling frame more representative of the population, it was also stratified into regions, to capture atleast the large maritime clusters:

	EU	West	Asia	FarEast	
Wetbulk Large	9 (2%)	6 (1%)	2 (0%)	10 (2%)	27 (5%)
Wetbulk Medium	88 (15%)	6 (1%)	14 (2%)	33 (6%)	141 (24%)
Drybulk Large	4 (1%)	3 (1%)	1 (0%)	10 (2%)	18 (3%)
Drybulk Medium	75 (13%)	11 (2%)	6 (1%)	49 (8%)	141 (24%)
Container Large	13 (2%)	0 (0%)	0 (0%)	11 (2%)	24 (4%)
Container Medium	37 (6%)	4 (1%)	2 (0%)	14 (2%)	57 (10%)
Mixed Large	23 (4%)	1 (0%)	4 (1%)	21 (4%)	49 (8%)
Mixed Medium	80 (13%)	1 (0%)	8 (1%)	54 (9%)	143 (24%)
	329 (55%)	32 (5%)	37 (6%)	202 (34%)	600

Major variables of interest (independent variables) were:

- Size – in the number of ships in a company fleet
- Chartering ratio – percentage of ships owned/chartered in and how this was chartered out
- Fuel use – annual fuel bill of the company
- Region – Companies mainly fall in to four categories namely; EU, West (US), Asia & Far East
- Sector – Companies operating their fleet solely in the wetbulk, Drybulk, Container sectors & companies with a mixed fleet (ships in two or more sectors)

Major variables of interest with the above (dependent variables) were:

- Uptake of a measure –10 operational/voyage measures
- Citation of a barrier – 7 barriers related to market barriers and market failures.

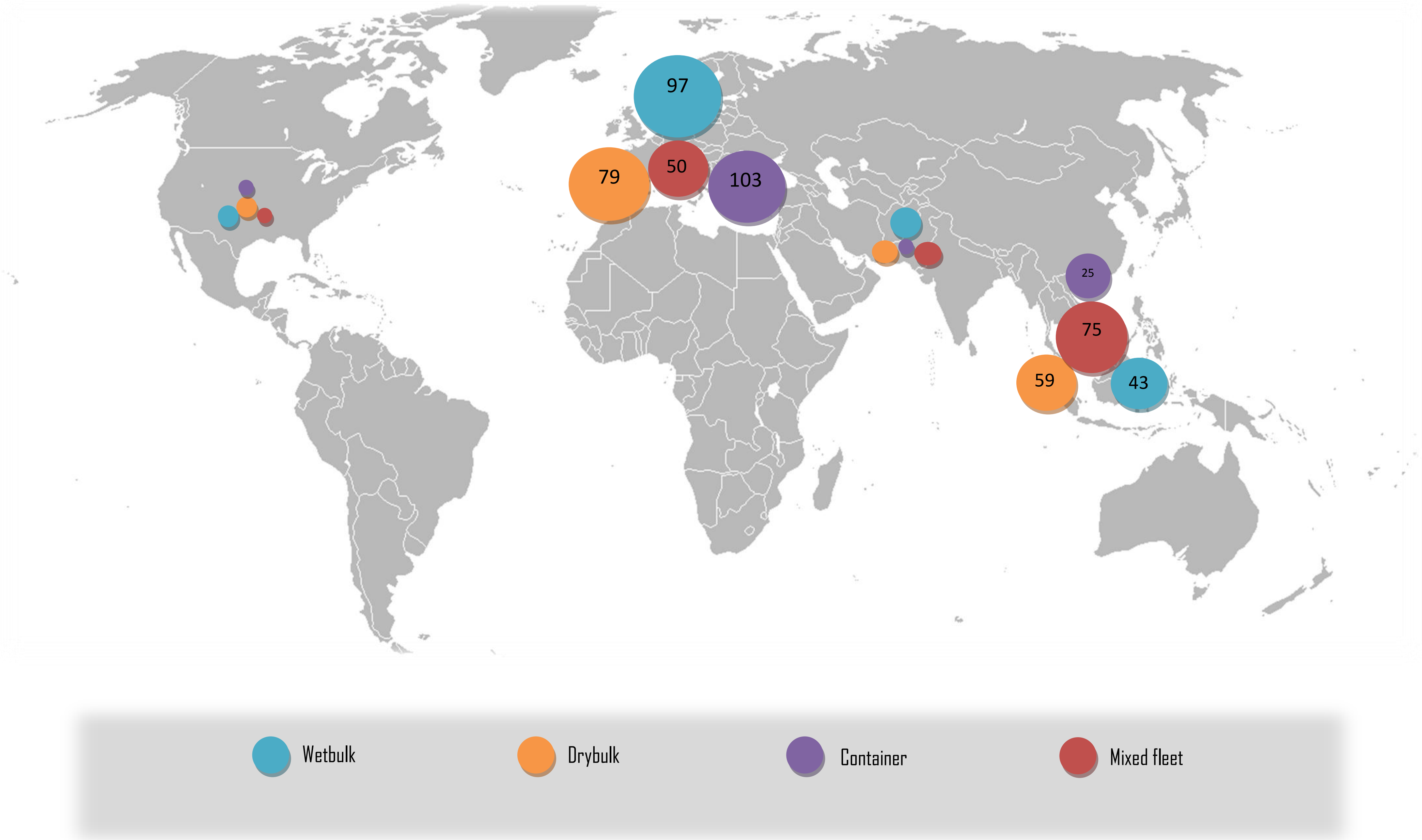
Independent variables (X):

Size (SCi) Categorical	Sector (Si) Categorical	Fuel Use (FUi) Categorical	Chartering % (Ci) numerical	Type of company (TCi) categorical
Large	Wetbulk	< = 100,000 = Low		Shipowner
Medium	Drybulk	100,001 - 499,999 = medium		Management company
Small	Container	> = 500,000 = high		Charterer
	Mixed			Owner-operator
				Shipping division of cargo owner

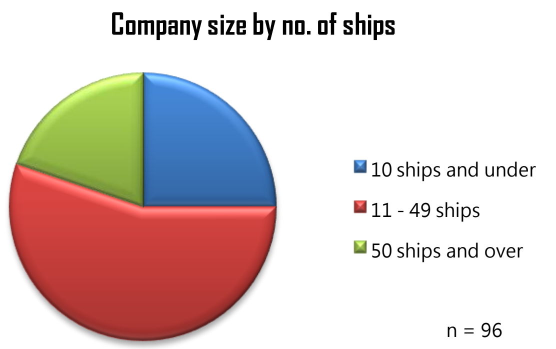
Dependent variables (Y):

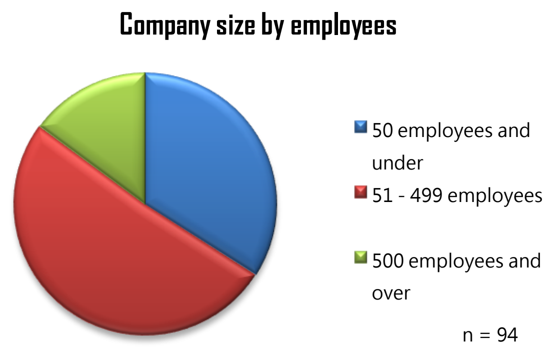
Uptake of measures (Mi) Categorical	Citation/frequency of barrier (Bi) Categorica/Numerical
1. Weather routing	Split incentives
2. Autopilot adjustment	Informational problems
3. General speed reduction	Risk
4. Fuel consumption monitoring	Lack of access to capital
5. Trim/draft optimisation	Hidden costs
6. Speed reduction due to port efficiency – JIT arrivals	General/other
7. Raising crew awareness & energy efficiency training	Heterogeneity
8. Efficient voyage execution	
9. Optimisation of ballast voyages	

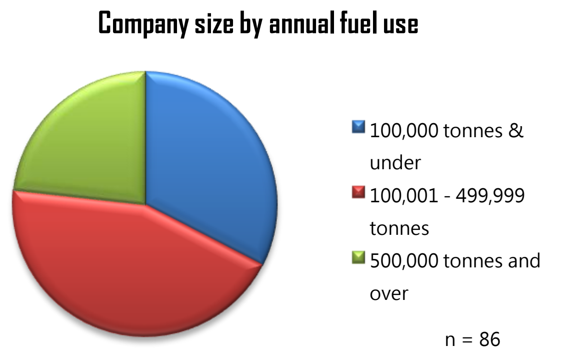
Global Maritime Clusters



Demographic profiles

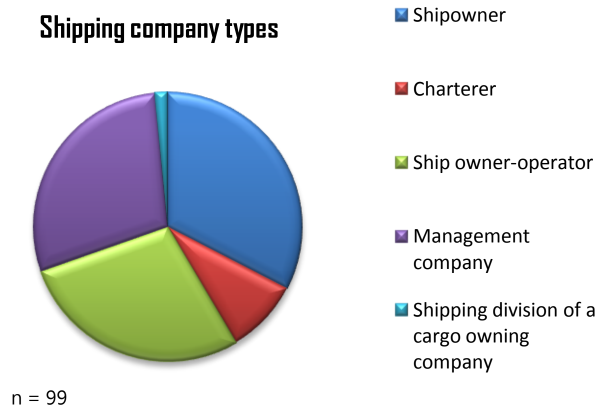


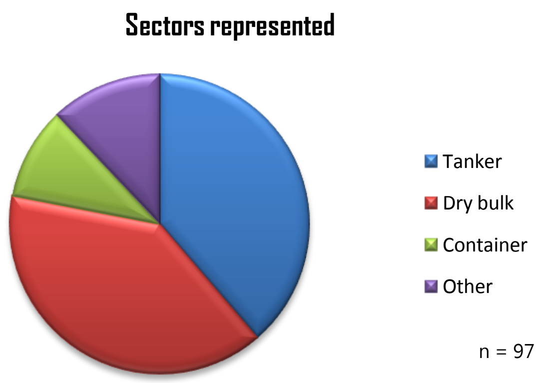




The questionnaire asked respondents demographic questions on the size of the company by number of ships, number of employees and annual fuel use with mutually exclusive choices. The responses from medium sized companies are approximately in proportion to the population.

The sampling frames represented well ship owning, operating and management companies but had very few charterers and cargo owners who had to be recruited from Clarksons fixtures. The question did not have mutually exclusive choices, hence the number of pure shipowning, operating and management companies was slightly lower. The actual numbers are presented in the following section.



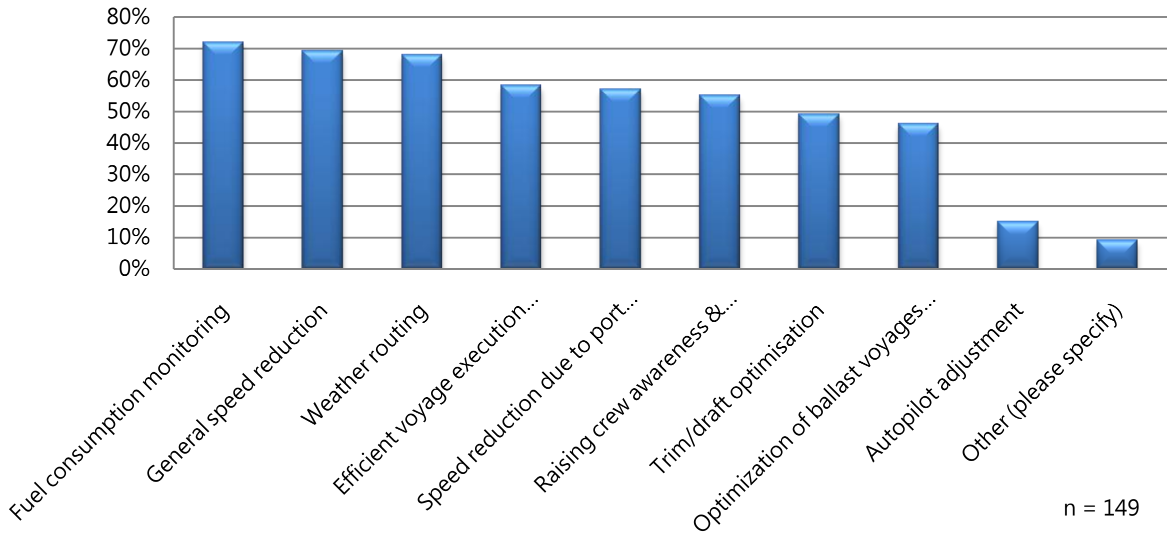


The survey was primarily focussed on the wetbulk, drybulk and container sectors. The responses from the wetbulk and drybulk are representative/proportionate to the population, however the container sector was significantly under represented. The question did not have mutually exclusive choices, hence the number of pure wetbulk, drybulk & container was slightly lower.

Key Findings

Respondents were first asked to select the top five operational measures that they believe have the highest potential in reducing fuel consumption.

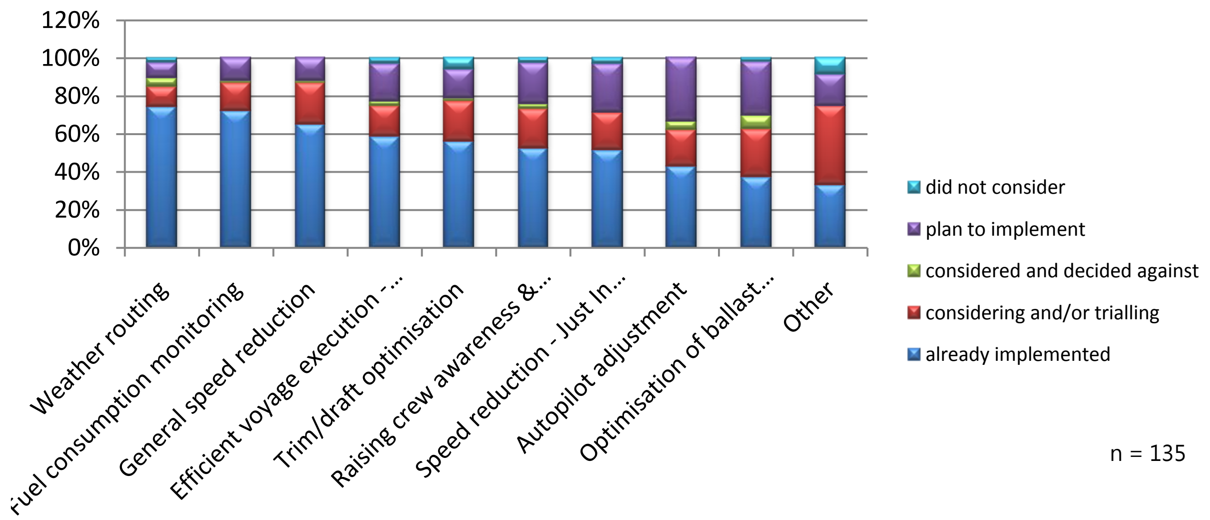
Figure 2: Operational measures believed to be of highest potential in CO2 reduction



For a list of measures and their description please refer to appendix A. Fuel consumption monitoring, general speed reduction and weather routing were cited as measures that have the highest potential. But does this hold for all the sectors? How will this vary according to company size, ownership and chartering ratio? The reasons that were cited for those who implemented the aforementioned measures were generally because savings from the investment could be fully recouped, the operations were under direct control and that there were no additional costs involved. These claims will to be further investigated in the later sections. Some respondents also cited other technical measures such as mewis duct, propeller upgrade etc, which were beyond the scope of this survey. In contrast to other measures autopilot adjustment ranked very low, perhaps due to the materiality of savings, which will be discussed later.

From the measures selected (above) by the respondents, the follow up question asked whether they have considered/implemented the measure they believed had the highest potential. Many MACC studies assume that measures with negative costs have been fully implemented or would have been/be implemented under certain fuel price. From the above it can be seen that even measures that were deemed to be of highest potential have actual implementation rate of around 65-85%. On average across all the measures the implementation rate is around 50%. Combing the already implemented and planning to implement categories, the average across all the measures is just under 70%. The answers to this question clearly show that despite the easiness of implementation and short payback (IMO/IMarEST inf.18) some measures still do not see 90-100% implementation. How much of this gap between the potential and actual be explained by the market barriers & failures? Could it be that the chartering ratio (operation in spot or time) or ownership has an influence in the implementation of the measures? How do the implementation rates vary according to sector?

Figure 3: Implementation of the measures selected



The respondents were then asked why they believed the measures they had not selected in the first question had lower potential for fuel savings. For the barrier categories and response choices refer to appendix B. In general the most pertinent barrier across all measures that were not selected (i.e. seemed to have lower fuel saving potential) were lack of reliable information on cost and savings, difficultly in implementing under some types of charter, lack of direct control over operations & materiality of savings, i.e. measures may be ignored by decision-makers due to their limited impact (AEA, 2008) (these, represented on average 50% of barriers cited for any given measure).

Some of the responses to this question indicate this;

"None of these are unattractive for investment, just not the top ones" - Global containerline

"Not always feasible" - Medium sized EU based shipping company

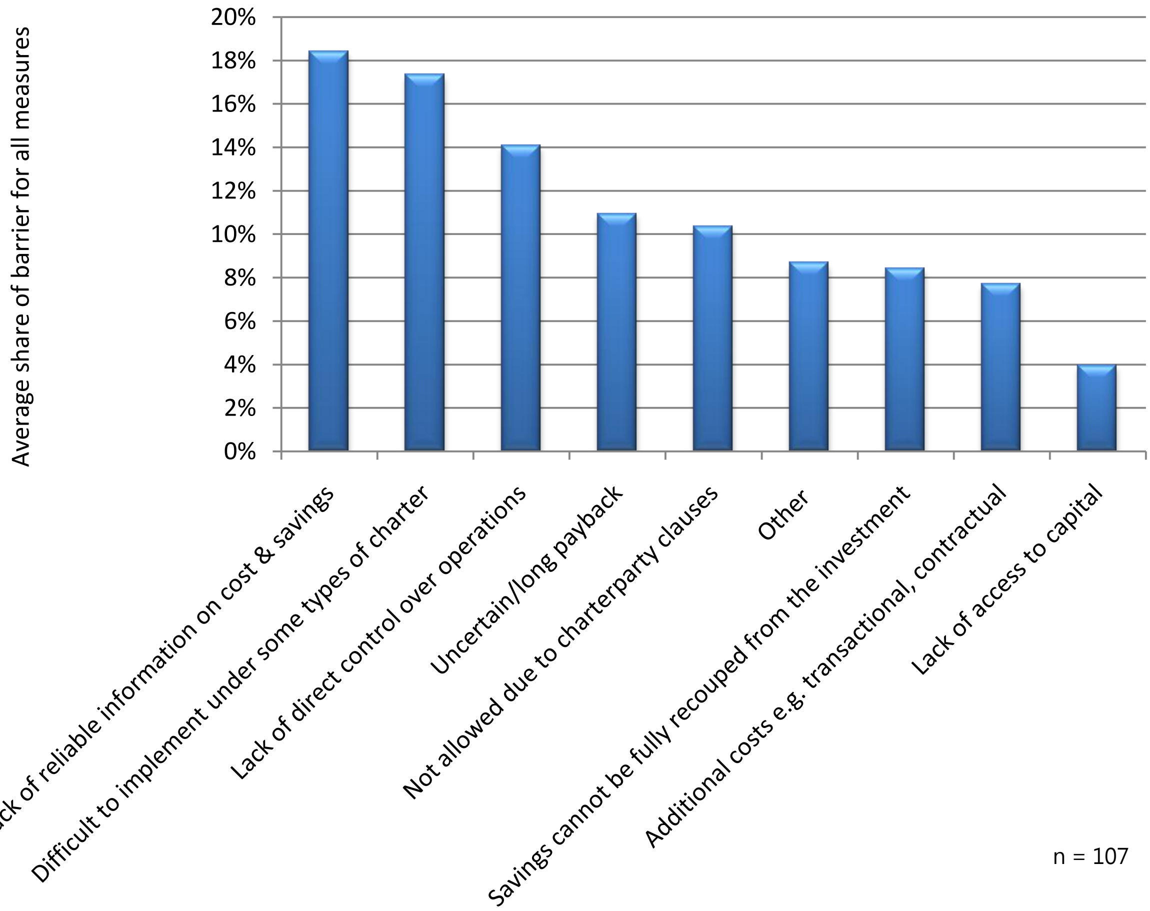
"Already being done but savings are less than measures" - Small US based shipping company

"Small effect" - Anonymous

"Impact rather low" - Large EU based shipping company

Analysing this in greater detail, it can be seen that there specific barriers for each of the measures. Lack or reliable information on cost and savings affects the potential for weather routing, autopilot adjustment, trim/draft optimisation and raising crew awareness & training. Weather routing and autopilot adjustment are mature technologies for which it would be expected that such information is readily and reliably available. There could be a proposition that this is the case for small and medium sized companies. Measures that were difficult to implement under different types of charter were mainly related to speed (general speed reduction and JIT arrivals) or had an element of speed (efficient voyage execution and optimisation of ballast voyages). The table can be further disaggregated by sector, size, chartering ratio and fuel use to see patterns/correlations.

Figure 4: Most important barriers for measures that were not selected as not having high savings potential



Most cited barriers per measure

Barrier \ Measure	Weather routing	Autopilot adjustment	General speed reduction	Fuel consumption monitoring	Trim/draft optimisation	Speed reduction JIT arrivals	Raising crew awareness & training	Efficient voyage execution	Optimisation of ballast voyages
Lack of reliable information on cost & savings	24%	26%	5%	12%	28%	9%	20%	15%	16%
Savings cannot be fully recouped from investment	5%	11%	10%	10%	7%	5%	14%	5%	8%
Difficult to implement under some types of charter	15%	7%	30%	5%	19%	26%	7%	26%	23%
Lack of access to capital	5%	5%	2%	5%	3%	4%	6%	0%	6%
Additional costs e.g. transactional, contractual	10%	8%	10%	14%	6%	7%	9%	4%	8%
Uncertain/long payback	10%	14%	5%	24%	14%	6%	18%	4%	8%
Not allowed due to charterparty clauses	3%	5%	26%	0%	4%	24%	2%	18%	12%
Lack of direct control over operations	18%	13%	10%	14%	11%	18%	10%	18%	15%
Other	11%	11%	3%	17%	8%	3%	14%	11%	4%

n = 107

The percentages show for each measure the number of responses for that particular measure divided by the total number of responses received for that measure.

Following the response from the second question (implementation), the respondents were either asked about factors that influenced their decision in implementing their chosen measures or factors that would prohibit them from implementing their chosen measure. Since this question is based on the respondent' s initial choice the actual response (n) varied widely but the response rate generally was just under 80%. Also note that not all measures had the same choice of factors, however some choices were always present to the respondent e.g. savings can be fully recouped, access to capital, direct control over operations. Despite always being available as response choice, access to capital was least cited as a factor influencing implementation, this tallies with previous response to the question on barriers to measures where lack of access to capital fared lowest amongst other categories of barriers. This shows that capital (cost/access) is not a deciding factor when operational/voyage measures are concerned and that there may be other hindrances or motivation to carry them out. As mentioned earlier reliable information on cost and savings of a measure was cited as a key barrier to implementation and from what can be seen below, it is suggests that when this information is available it can be driving factor for implementation. The key factor in driving implementation of the operational measures was that the savings can be fully recouped from the investment (i.e. non existence of split incentives), which was however hardly cited as a barrier in the previous question. This requires further analysis of each of the respondent' s demographics to see how much fuel is used and who pays for fuel using their chartering ratio. Some of the responses are shown below:

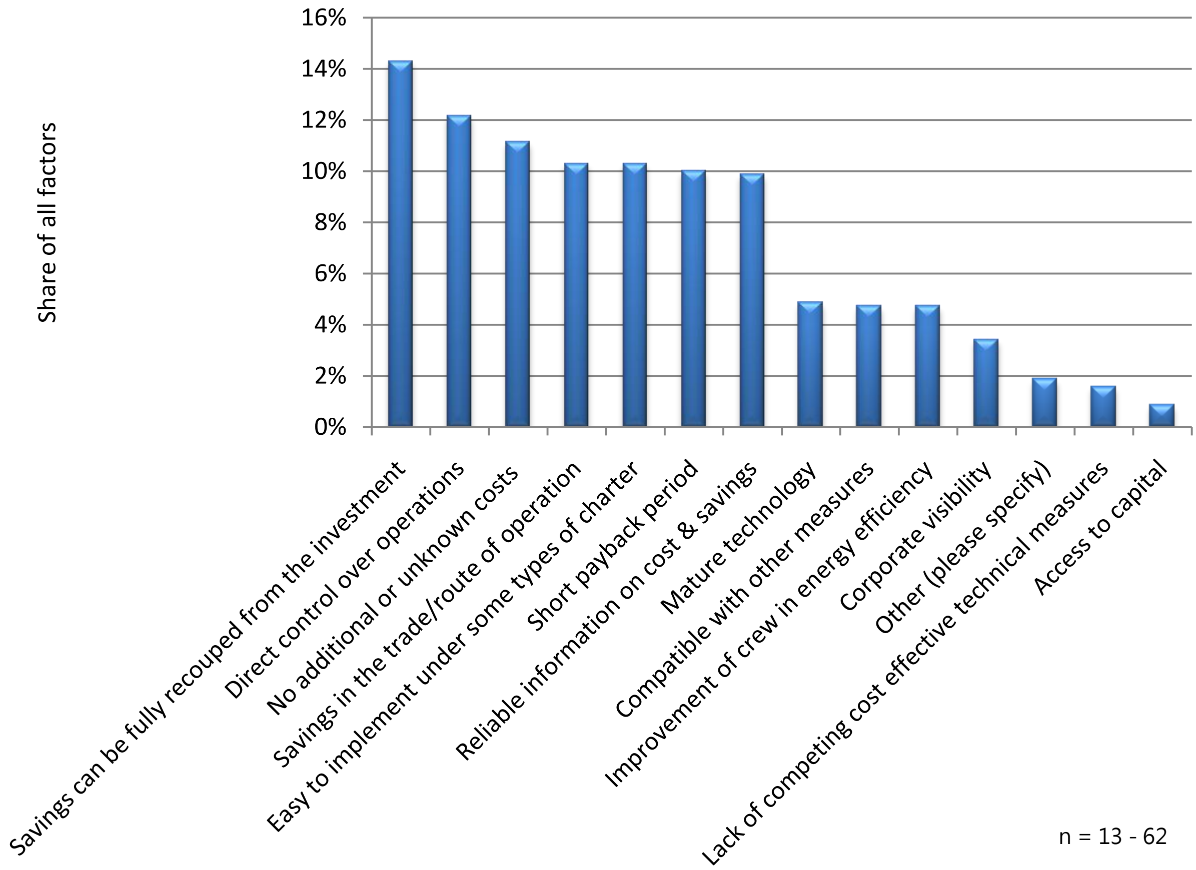
Far East Global Container line on anti-fouling coatings:

"Despite the initial investment the results have been very successful with short periods for return on investment.
1) Reduced fuel consumption
2) Shorter stay in drydock for future drydockings
3) Good for the image of the company"

Large Dry bulk shipping company on regular underwater grit blasting in dry dock and use of premium low friction anti fouling systems:

"no brainer - restoring the underwater hull profile to/close to original reduces frictional resistance in service and will reduce fuel consumption by at least 6% if done every 10 years. Superintendents in dry dock could, if their budget is under pressure, reduce on grit blasting and painting to balance their budget - this at the expense of future fuel consumption - in setting out this policy we have taken away their right to reduce this blasting and it is defined company policy increasing fuel prices and a worsening market in 2008 focused attention on fuel saving initiatives - this was the first and easiest to implement"

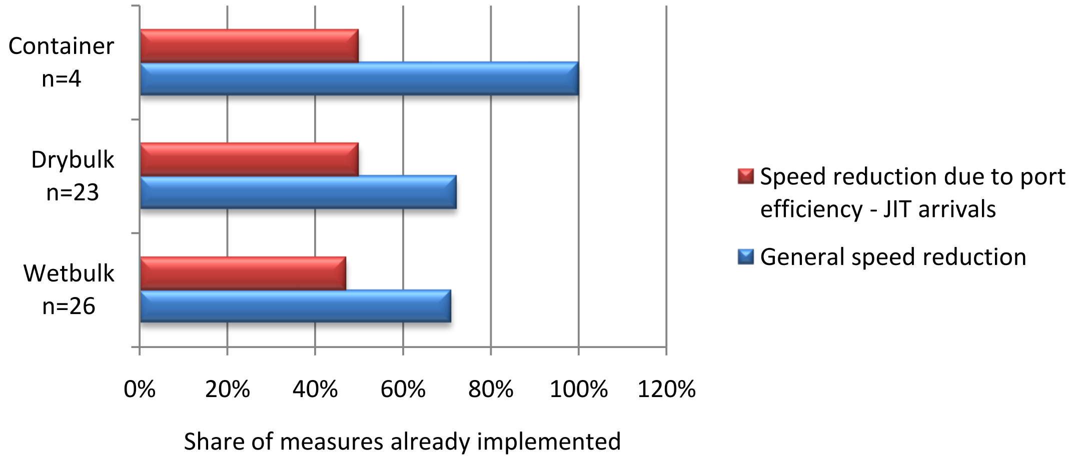
Figure 5: Factors leading to implementation



Analysis of measures related to speed

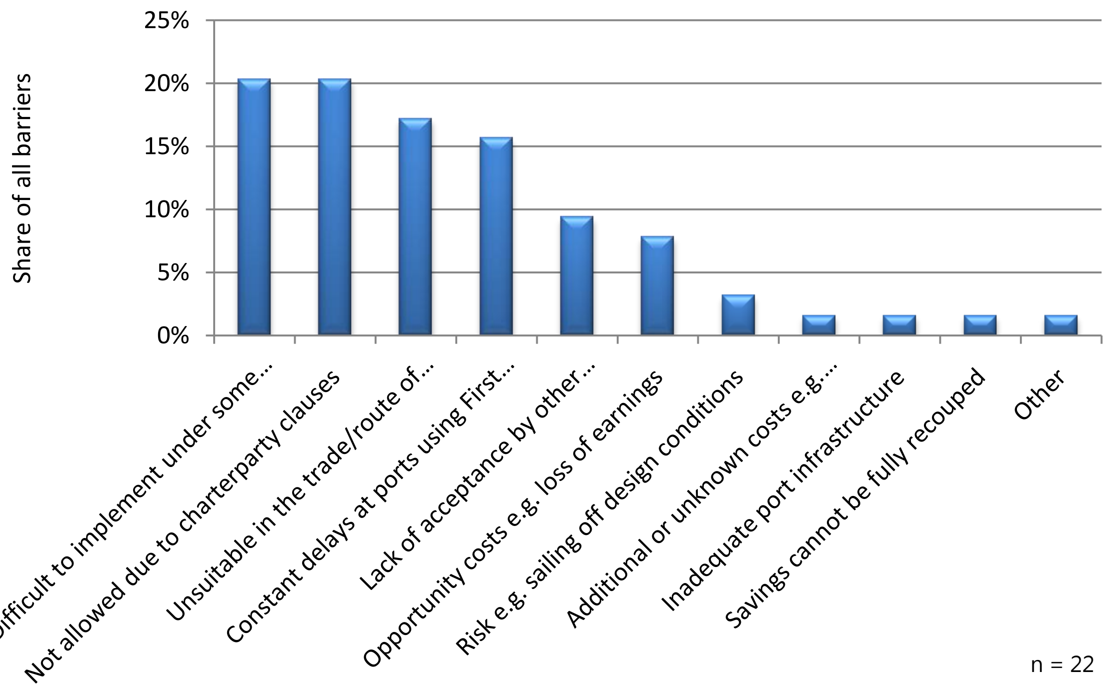
Earlier it was seen that general speed reduction had implementation rate of around 70% on average for all those who saw this measure to have a high savings potential. Decomposing this by sector, it can be seen that the wet and dry bulk sectors have similar implementation rate, with the container sector having 100% implementation of the measure (this is however not necessarily representative of the whole sector due to the small sample size). Speed reduction due to port efficiency – Just In Time arrivals, has much less penetration than the general slow steaming measure as it requires many parties/stakeholders to come together, share information and act upon the information with an increased role by the port/terminal operators. Lack of information sharing between stakeholders was cited by 30% of the 99 respondents who answered the question on barriers to speed reduction.

Figure 6: Speed measures already implemented



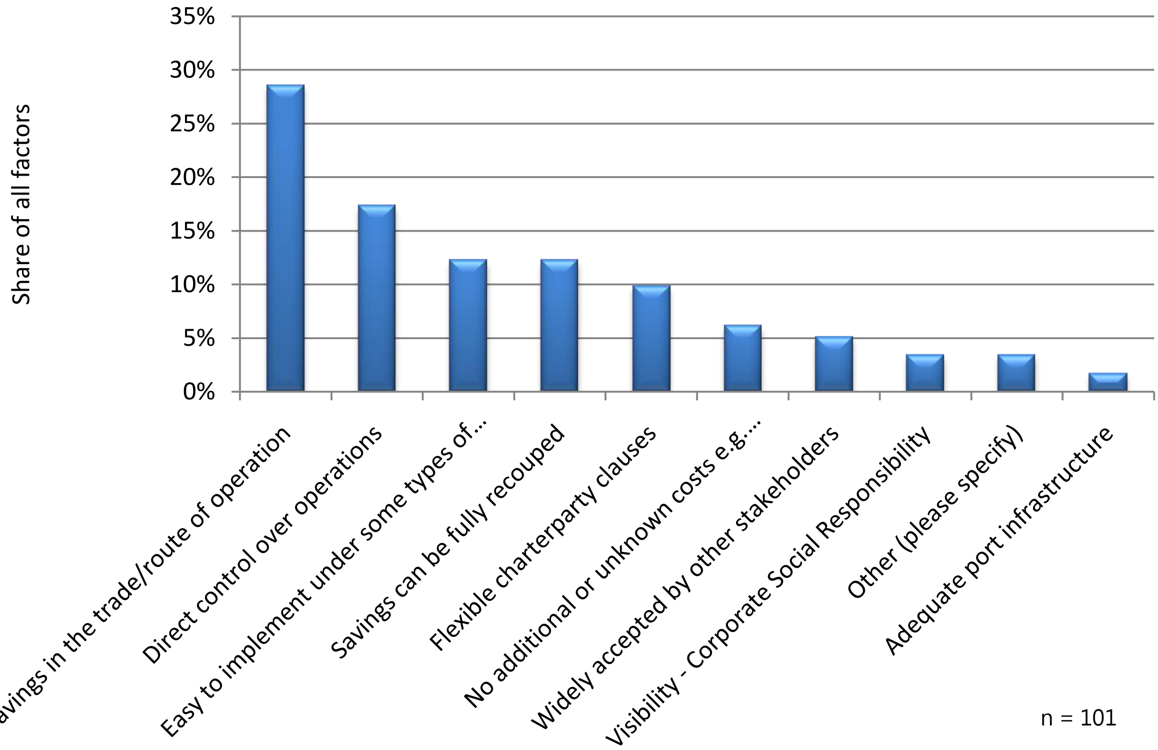
The respondents who selected considering/trialling or considered and decided against speed related measure were asked which of the following barriers would prohibit them to implement such a measure. It was clear from their responses that most of them believed it would be difficult to implement such a measure under different types of charter and that charterparty clauses were also an important hurdle. For most it is also the case that there may not be enough savings due to the nature of their operations or the costs may outweigh the benefits of such savings e.g. piracy. Respondents did not think that there was significant risk in sailing off design conditions.

Figure 7: Most important barriers for speed related measures



The respondents who had already implemented or planned to implement speed related measures were asked which of the following factors had the most influence on their decision to implement. The result shows that the speed related measures will only be applied if there are sufficient savings in the trade/route of operation, which reflects the heterogeneity of the shipping industry, as not all sectors and trades are the same e.g. coastal shipping and feeder services. Following this factor, the three most important factors (direct control over operations, easy to implement under different types of charter & savings can be fully recouped) need to be analysed in context of the chartering ratios of the companies in order to examine whether the implementation of measures is affected by the different chartering arrangements of the company.

Figure 8: Most important factors for implementing speed related measures



Medium sized tanker owning company – "Market forces- given very low charter rates, a vessels fuel consumption have become very important"

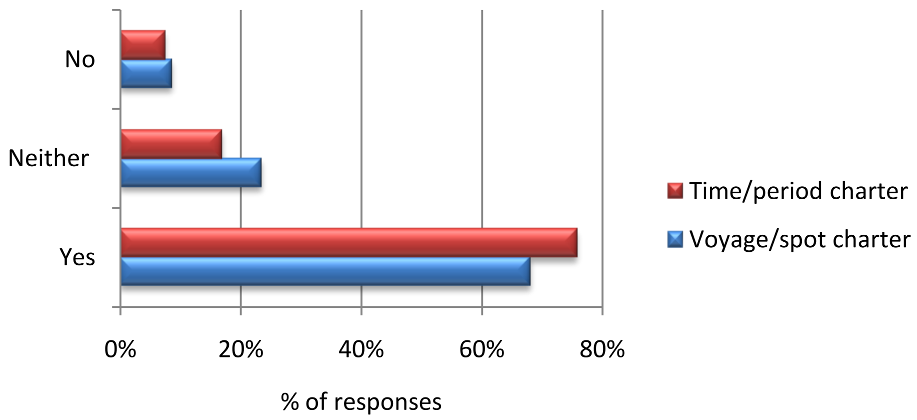
Medium sized dry bulk company – "most efficient measure of all"

Some of the respondents also noted that it is the charterer who sets the speed in time charters and that the shipowners were not in control of this under this charter. This to some extent agrees with following question that asked whether speed reduction is achievable in time/voyage charters. There was very small difference in achievability of speed reduction under voyage and time charters.

Large Ship management Company – "Requested by Charterer"

Anonymous – "Charterers' instructions on Time Chartered vessels"

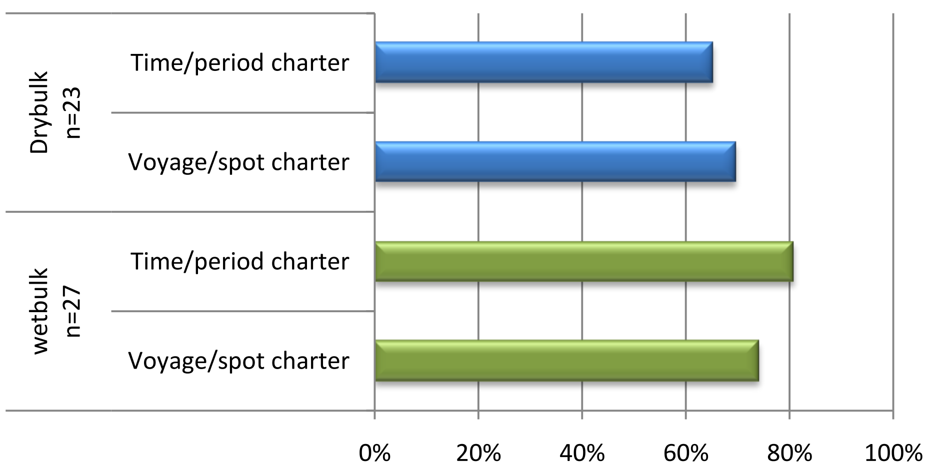
Figure 9: Achieving speed reduction under different types of charter



n = 95

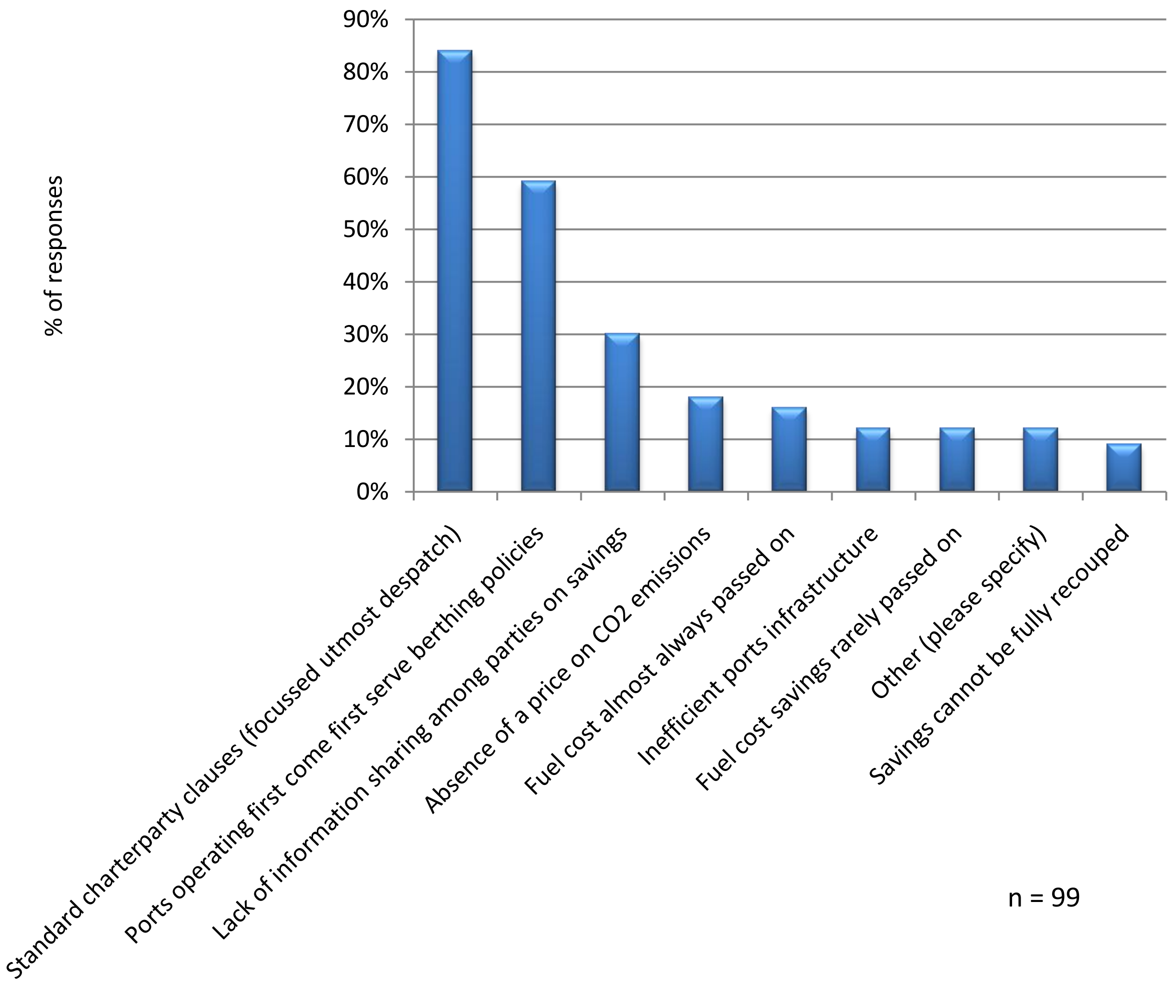
A recent report by Poten & Partners (2011) suggested that vessels on time charter were less likely to slow steam than vessels on spot market vessels, because charterers, who pay for bunkers supplied to their time chartered tonnage, are more likely to consider the schedules of their trading or refinery programmes in adjusting vessel speeds than possible savings on fuel costs. There was also a small difference when the responses to the above were broken down according to wetbulk and drybulk sectors.

Figure 10: Achieving speed reduction under different charters



The last question of the survey asked respondents (regardless of their selection of speed related measures in q1 and whether it is being trialled or already implemented), what they thought were the three most important factors that might prohibit speed reduction. Risk associated with sailing off design conditions/engine limits was cited much less when asked to respondents who were already considering/trialling speed reduction in comparison to this question which was asked to all respondents. Some of the responses are shown below:

Figure 11: Most important barriers to speed reduction



Large tanker shipowner – "Stakeholder (customer) demands"

Large tanker pool/operator – "Voyages fixed at slow speed anyway. We cannot slow down further than the engine will allow - running an engine at slow speed entails operational difficulties. This is the biggest single reason we cannot move ships glacially slow at the moment"

Large container line – "Competition between shipping lines"

Large drybulk shipowner – "Non-commercial due to high hire rate"

Medium sized drybulk and container shipowner – "Engine design"

Medium sized drybulk management company – "Freight Rates"

Large mixed fleet shipowner – "Main engine limits"

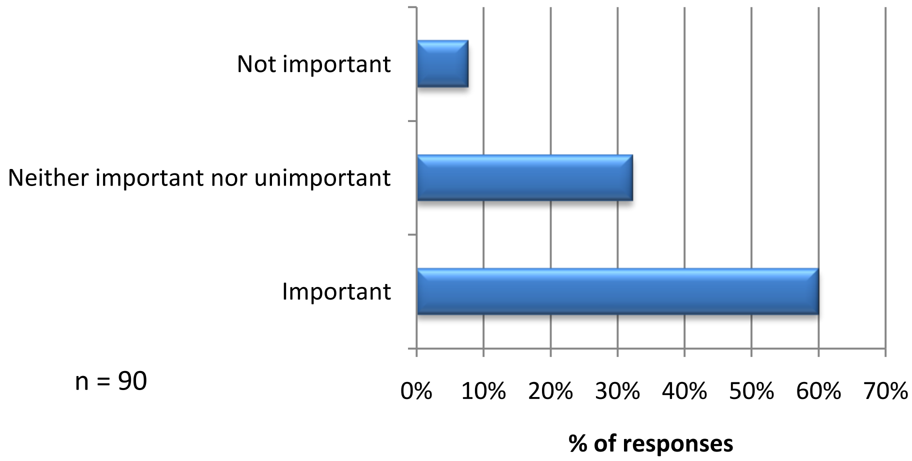
Medium sized drybulk management company - "Ship engine not designed for long navigation at reduced speed"

Small tanker management company - "Technical problems"

Medium sized shipowner and management company – "Charterer orders"

Energy Efficiency Design Index

Figure 12: EEDI as an informational tool during selection



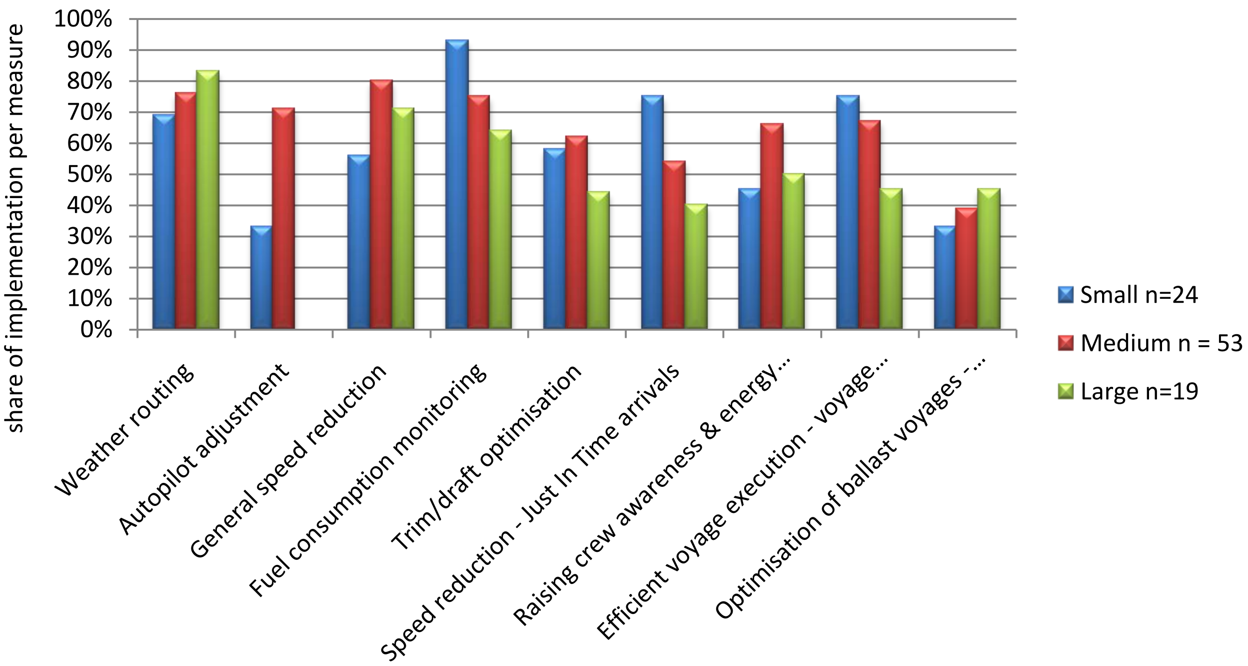
The Energy Efficiency Design Index (EEDI) could be used by potential charterters and shipowners to better evaluate a ships fuel efficiency. Although designed for new builds, its application to the existing has gained much traction and providers such as shippingefficiency.org and Rightship have created databases for this purpose. 60% of the respondents thought that the EEDI was important during the selection process. A similar survey by Faber et al (2011) found that respondents disagreed that EEDI and other indicators of fuel efficiency would increase transparency and allow owners of efficient ships to command higher charter rates and some thought that it would allow for gaming.

Discussion

This section looks at some of the responses in greater detail in light of the various independent variables aforementioned. Although a representative sample was achieved (for most independent variables) with which inferences can be made to the population (with some margin of error), no attempt is made at this moment to generalize the findings to the general population. The discussion is for the purposes of gauging interest in the various possible reasons for why some measures are being implemented and why some are being left on the table.

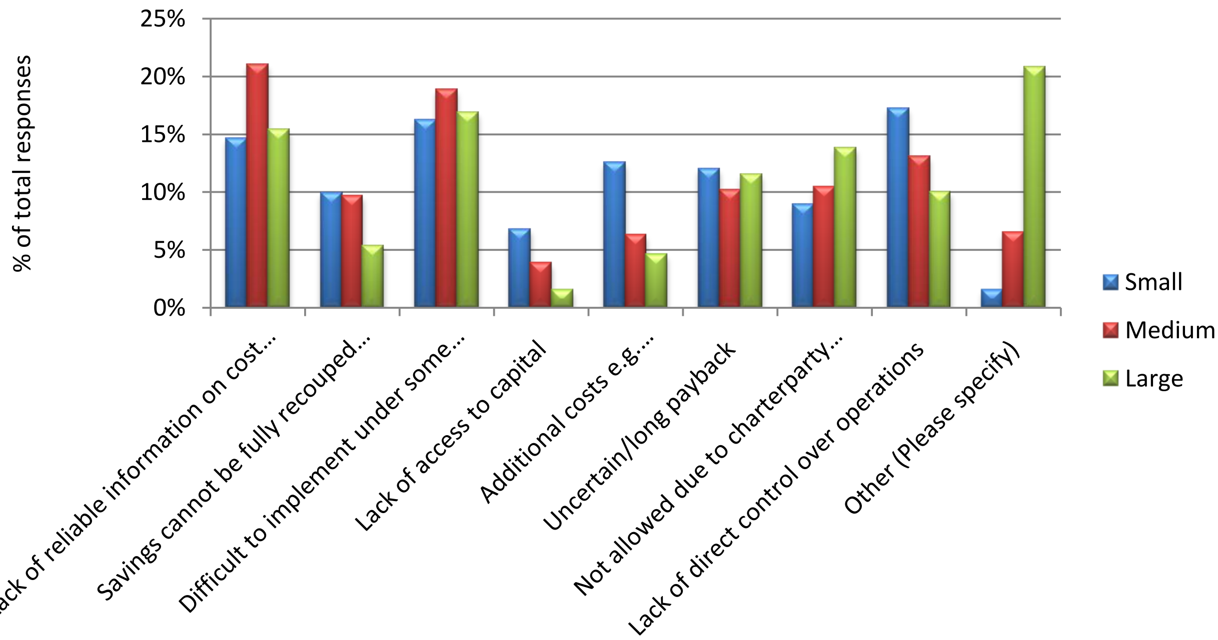
Weather routing, fuel consumption monitoring and general speed reduction had the highest implementation in comparison to other measures. When disaggregated according to the size of companies, the results show some interesting patterns. For some measures such as fuel consumption monitoring, speed reduction JIT arrival and efficient voyage execution the smaller companies have a higher implementation than compared to medium and large companies. The small companies also cite access to capital over three times more than large companies and twice as much as medium sized companies. This difference in implementation rate could perhaps be due to the small sized fleet which may make investment manageable or conversely the large sized companies not investing due comparatively higher outlay. Further analysis of the data shows that the larger companies are still either considering/trialling or planning to implement those measures.

Figure 13: Measures already implemented by different sized companies



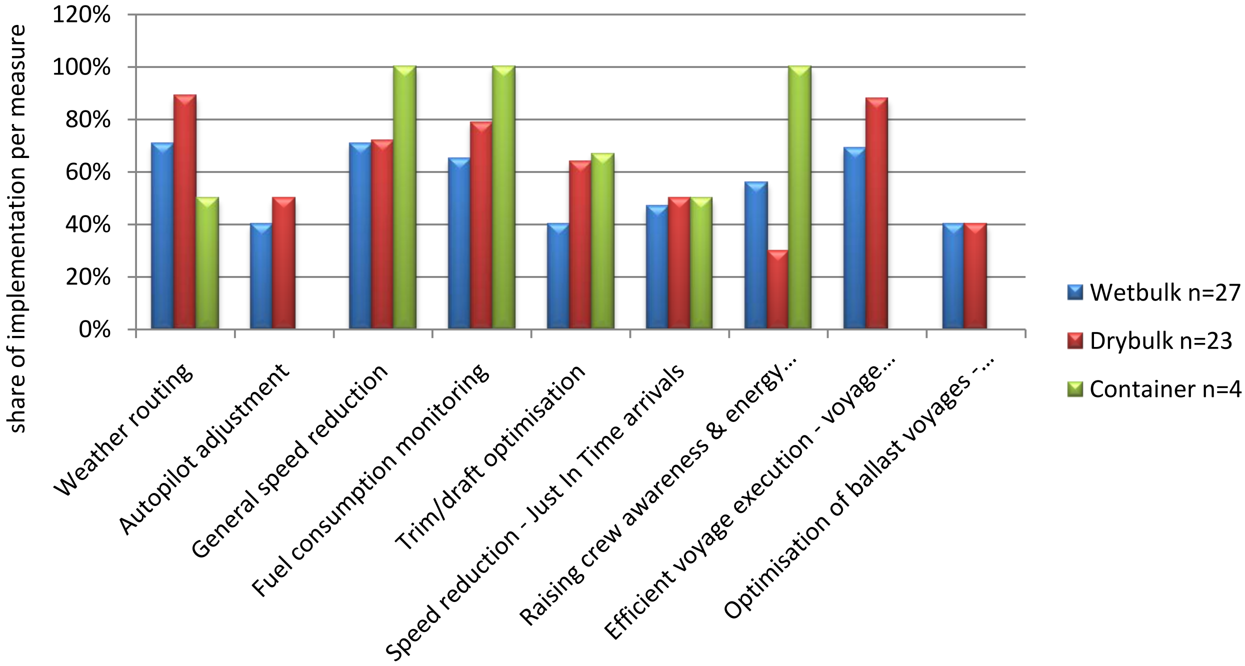
As shown earlier in figure 4, lack of reliable information on costs and savings, difficulty in implementing under some types of charter and lack of direct control over operations were the top three barriers that were cited. For these three barriers the responses are similar for large and small companies except for lack of direct control over operations. Looking at the chartering ratio of the small and large companies reveals that majority of the small companies have a higher proportion of their fleet chartered out on time charter & bareboat basis than on voyage and COA charter in contrast to larger companies which have more of their chartered out on voyage charter basis. Additional costs also seem to be negatively correlated with size of companies. More large than small companies also cited that some measures such as (speed reduction, autopilot adjustments, optimisation of ballast voyages) were not allowed due charterparty clauses, despite their bargaining power that is generally assumed.

Figure 14: Most important barriers for measures that were selected as not high savings potential

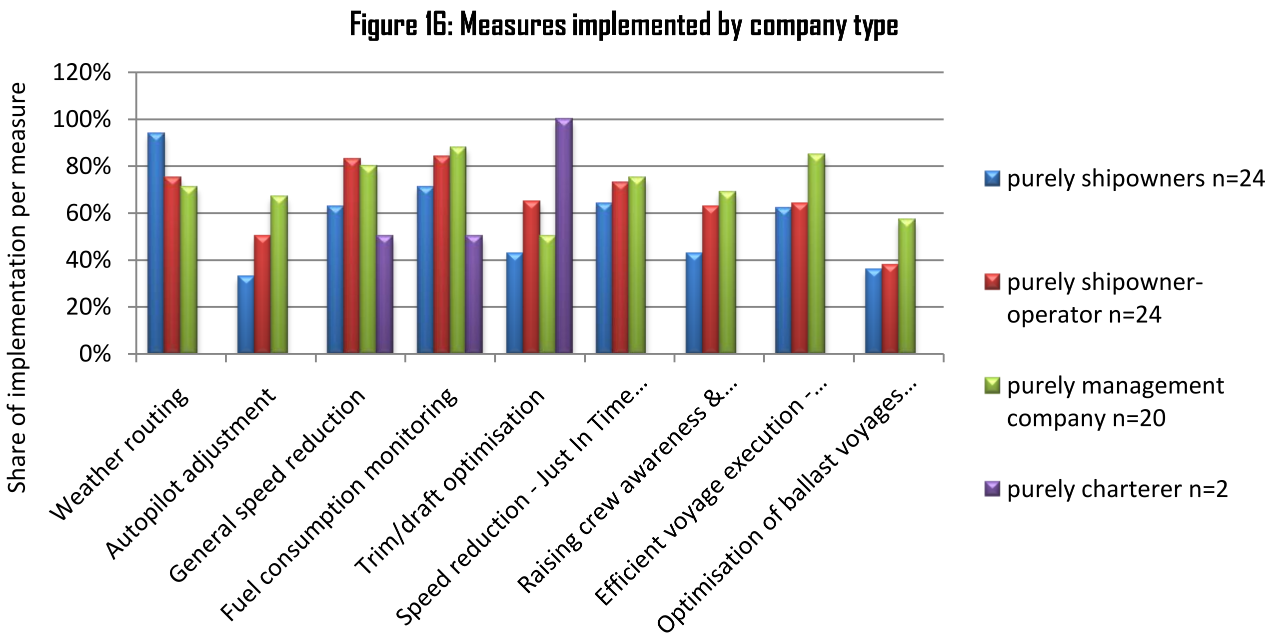


Although a technology may be cost-effective on average for a class of users taken in aggregate, the class (e.g. panaxmax container ships, specific routes, commodities) itself, consists of a distribution of owners/operators: some could economically purchase additional efficiency, while others will find the new level of efficiency not cost effective (Sweeney, 1993). This heterogeneity is a result of operation in different sectors (including different types and classes of ships), geographical markets (which also brings. access/lack of access; to capital and reliable information), trade/route of operation, difference in ownership structure and type of charter.

Figure 15: Measures implemented by companies operating in different sectors



The above chart shows the various rates of implementation of measures for companies operating solely in wetbulk, drybulk and container sector. As shown earlier in figure 3, general speed reduction, weather routing and fuel consumption monitoring were the top three measures with the highest implementation. When these are disaggregated according to sector, it can be seen that general speed reduction and fuel consumption monitoring have highest implementation in the container sector and almost similar rates in the wet and dry sector. Some of this could be explained by type of charter most prevalent in that sector. The tanker and dry bulk sector have a higher ratio of ships chartered in and out on spot charter basis in contrast to container which has little/none on this type of charter. A brief analysis of chartering data shows that the four responses received from sole container companies were all from owner-operators with majority of the fleet that was owned or chartered in and out on time charter basis. Although anecdotal, could this hint towards the ability or inability to recoup savings from the investment? Disaggregating the implementation of measures by the ownership structure or company type does not reveal any stark differences between these. Although there were differences across implementation rates by different type companies for each measure, across all measures the average implementation for shipowners was 57%, shipowner-operators 66% and management companies 71% .



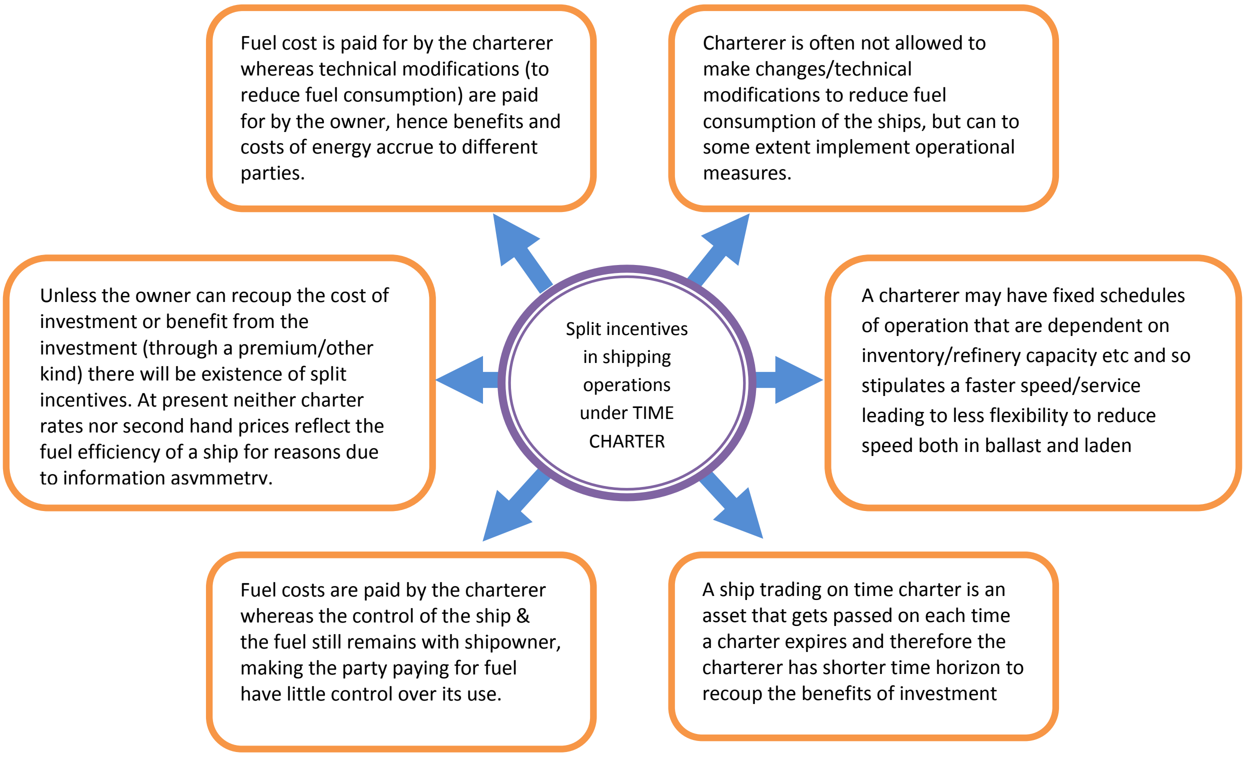
Literature on barriers pertaining to shipping have largely pointed towards informational problems (information scarcity, reliability, and asymmetry) and split incentives. These barriers have also been investigated in greater detail in the building & manufacturing industry. Generally they can be classed as principal-agent problems due to the existence of two or more agents with varied (and often conflicting interests). However, much of the literature on these barriers in different industries has focussed on capital intensive and technical investments to prove its existence, see for e.g. IEA (2007), Sathaye et al (2004), Sorrel et al (2000). In shipping for example "Perhaps one of the biggest institutional barriers to implementing fuel saving projects that require capital investments (e.g., waste heat recovery systems) is the divided responsibility or 'split incentive' between shipowner and charterer for fuel costs" IMarEST (2010). How do these barriers impact the uptake of the relative low capital investments, which have much to do with actual operations (voyages), where even the most energy efficient measure may fail to provide savings due to human elements such as improper use, attitudes/values, rules of thumbs & bounded rationality.

Informational problems and uptake of operational measures

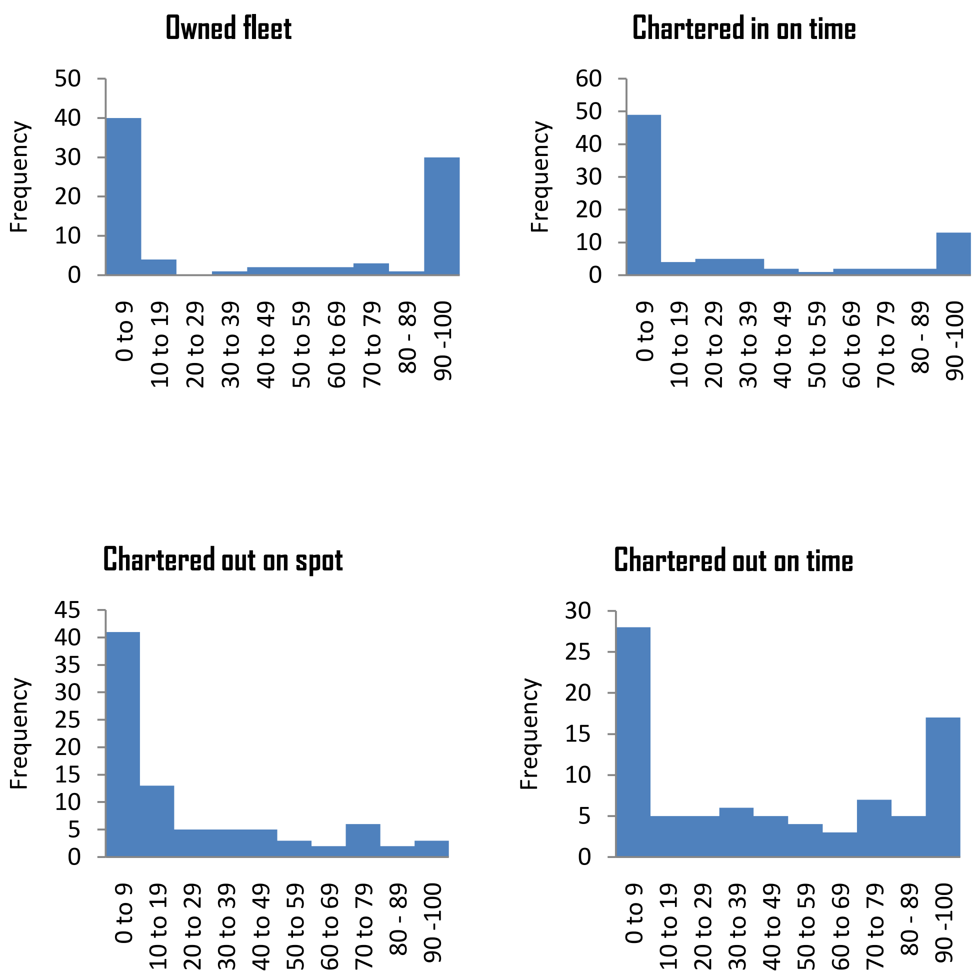
Of all the barriers cited by respondents, lack of reliable information on cost and savings was the highest cited barrier in many questions. When respondents were asked as to why they thought a measure had low potential they believed so because of lack of reliable information on costs and savings. Thus the costs of acquiring reliable information may outweigh the savings of a particular measure. This barrier was pertinent to weather routing, autopilot adjustments, trim/draft optimisation & raising crew awareness on energy efficiency. There have been several attempts by the industry to address the issue of informational problems for both operational and technical measures such as the Ship efficiency guide by Fathom (2011) and DNV (2012). However once again due to the heterogeneous nature of the industry the assumptions made in these may not be applicable to all. The size of the company is almost perfectly negatively correlated to the number of respondents citing lack of reliable information on cost and savings. Small companies more frequently cited this as a barrier in comparison to large companies. The informational problems could also be translated to hidden costs (requiring extra staff time/evaluation etc). According to AEA (2008) hidden costs for operational measures are likely to be higher than those for technical measures due to the large number of stakeholders involved in their implementation (e.g. all crew members would need to be involved). What role can classification societies and energy services company play in mitigating this 'low cost' (AEA, 2008) barrier?

Split incentives affect the uptake of operational measures

The split-incentives problem is where the costs and benefits of energy efficiency accrue to different agents (Howarth & Winslow 1994). In shipping, due to different the different types of charter, costs and benefits do not accrue to the investing party; hence savings cannot be fully recouped/appropriated.



From the survey the second and third most cited barrier (after informational problems) was that it would be difficult to implement the measures under some types of charter followed by lack of direct control over operations, which is also a result of the different types of charter and increases the split incentive i.e. party paying for fuel is also not in control of its use. There was also difference when these results are looked in light of the different sectors; respondents citing this as a barrier from the container sector were less than half than that of bulk sector. In relation to other barriers, the inability to recoup fared fairly low, for those respondents who were considering/trialling a measure. However, for those who had already implemented the measures the ability to recoup the savings from investment was the most important factor alongside direct control over operations. This suggests that the different chartering arrangements/ratios may be barrier towards uptake of operational measures. Below is a summary of the respondent companies chartering ratios.



A Sustainable Shipping article and poll on split incentives and uptake of exhaust gas scrubbers asked readers to poll on the following question "Is the relationship between a shipowner and charterer preventing companies from investing in scrubbing technology?" Almost 60% thought yes, just over 10% said no and 30% said only in some cases. "This split incentive can leave owners reluctant to spend significant amounts on technologies that will not benefit them directly, beyond perhaps making it a little easier to find charterers for their vessels" Sustainableshipping.com (2011). According to Faber et al (2011) the split incentive can to a degree be remedied by providing the market with good metrics to evaluate the fuel-efficiency of ships and the EEDI could be one of them. Heisman & Tomkins suggest that one approach could be to change the contracting structure, so that the fuel costs are borne by the shipping companies. This would have the effect of aligning incentives for fuel conservation. This also requires some measure of transparency so that charterers can identify the most efficient ships, which once again leads to the informational problems.

Conclusions

Literature has shown through MAC analysis that there are negative costs associated with various abatement options available to shipping. The negative costs (which should save fuel/money for the party investing in the measure, a win-win situation in terms of policy) have been explained either by inaccurate representation of risk and costs and/or the existence of market barriers and failures. The survey was an attempt to understand directly (through respondent choices) and indirectly (through analysis of chartering ratios) what barriers are actually faced by companies in their decision to implement such operational measures. It was clear from the survey that informational problems such as the source/reliability of information, lack of information sharing (asymmetry) were prevalent atleast to the survey respondents. From the survey, the barriers to uptake of operational measures could also be explained by the inability to recoup savings from investment, lack of direct control and difficulty in implementing measures due various contracting structures, which are a result of the different chartering arrangements/ratios. Other factors (which are not market barriers) such as size of companies and ownership structure/type of company and heterogeneity of individual companies also explained why negative costs (energy efficient) are not taken up (i.e.no longer economically efficient).

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Appendix

A) List of measures and their description

No.	Measure	Description
1	Weather routing	There are weather routing services available that help to optimize the route a ship takes, given the corresponding weather conditions. Reduction of travel time leads to a reduction of fuel consumption. A significant portion of the world's fleet already employs this technology, but is it actually used and by who?
2	Autopilot adjustment	Adjusting the autopilot to the route and the operation area prevents unnecessary use of the rudder for keeping the ship on course. Once again, significant portion of the world's fleet already employs this technology, is it actually used?
3	General speed reduction	By operating at lower speeds, ships reduce their power requirement and hence their fuel consumption. As a rule of thumb, power requirement is related to ship speed by a third power function. This means that a 10% reduction in speed results in an approximate 27% reduction in shaft power requirements.
4	Fuel consumption monitoring	Real time monitoring of energy consumption . The monitoring of fuel consumption is regarded to have a high potential, especially for crew awareness training.
5	Trim/draft optimisation	The trim that is optimal for a vessel under the different conditions can be detected by means of monitoring. Trim can be improved by arranging bunkers, by positioning cargo or by varying the amount of ballast water. Taking extra ballast water thereby leads to an increased displacement and therefore to an increased fuel consumption.
6	Speed reduction due to port efficiency – JIT arrivals	The ship operator and the charterer stipulate a certain speed in the charter party. In case of port congestion, this contracted speed is not the optimal speed when it comes to fuel consumption; the ship could have been unloaded at the very same time but could have saved fuel by reducing its speed at sea. Concepts like the virtual arrival try to tackle this common problem.
7	Raising crew awareness & energy efficiency training	Increasing the energy awareness of the crew by means of training can lead to a change of behaviours that have an impact on the fuel consumption of ships. Energy awareness means turning off lights, optimising HVAC etc.
8	Efficient voyage execution – Voyage	Ships often do operate without fully making use of their cargo loading capacity. If the load factor of ships was increased, the

	planning & DWT utilisation	emissions of these ships would increase due to the increased weight of the vessel, however, this increase would be outweighed by the emissions saving of using a smaller number of ships.
9	Optimisation of ballast voyages – speed reduction	Reducing speed in ballast voyages when not bound by charterparty speed limits

Source: Buhaug et al. (2009), IMarEST (2010), Faber et al (2011)

B) Response choice and which barriers category does each fall into.

No.	Barrier	Response choice
1	Split incentives	a) Savings cannot be fully recouped b) Lack of direct control over operations c) Difficult to implement under some types of charter
2	Informational problems	a) Lack of reliable information on cost & savings b) Lack of information sharing among parties (speed)
3	Risk	a) Uncertain/long payback b) Immature technology c) Sailing off design conditions
4	Lack of access to capital	a) Lack of access to capital
5	Hidden costs	a) Additional costs e.g. transactional
6	General/other	a) Not allowed due to charterparty clauses b) Inadequate port infrastructure c) Corporate/visibility
7	Heterogeneity	a) Unsuitable to trade/route of operation

Annex

Draft discussion Paper: What are the implementation barriers to low carbon shipping?

Nishat Rehmatulla and Tristan Smith, UCL Energy Institute. October 2011.

To meet any future incentive (economic or regulatory), a number of options exist for either the increase of energy efficiency or the abatement of CO_2 and GHG emissions. These options can be applied to newbuild ships and in some cases also for retrofit to existing ships. Examples of attempts to compile lists of these options, their characteristics and economic attractiveness can be found in IMO 2010a. For example:

- drag reduction
- propulsion energy efficiency increase
- energy and machinery decarbonisation and efficiency increase
- operational changes

In each case, specifying changes from standard technology (those associated with the existing low cost, volume ship building) incurs costs, but can also provide a benefit. That benefit could be an increase in energy efficiency (which will have an economic impact dependent on the fuel price), the satisfaction of a policy for carbon abatement, or a reputation gain associated with a reduction in environmental impact.

A common method of presenting analysis of the order in which options might be adopted and the likelihood of investment, particularly for policy work, is the Marginal Abatement Cost Curve (MACC), examples of which for shipping can be found in Faber et al. 2009, Bauhaug et al. 2009, IMO 2010a, IMO 2010b, Det Norske Veritas 2009.

Besides the inherent shortcomings in MACC analysis (Kesicki 2010), for shipping it is commonly undertaken with an incomplete representation of costs and little representation of risk (beyond the investment rate of return). The result from the referenced analyses has so far been the identification of substantial (e.g. up to 30%) unrealised abatement potential using options that often appear to be cost-negative at current fuel prices. This contradicts the logic that a competitive industry with a dominant energy cost should be overlooking opportunities to increase efficiency at a profit. Possible explanations are that either:

- Models for analysis are inadequate for representing costs/benefits of low carbon and energy efficiency investment or the data used are incorrect; or
- Other implementation barriers/failures exist which are obstructing the shipping industry' s implementation of low carbon

It is possible to gain some insight into the relative significance of each of these explanations, by looking at how this work has been discussed by others both for shipping and other industries. Survey work is also under way to attempt to quantify the relative importance of the possible explanations.

What are the possible omissions from the existing analysis/data?:

Heterogeneity –although a technology may be cost-effective on average for a class of users taken in aggregate, the class (e.g. panaxmax container ships, specific routes, commodities), itself, consists of a distribution of owners/operators: some could economically purchase additional efficiency, while others will find the new level of efficiency not cost effective (Sweeney 1993).

Risk - technologies are assumed incorrectly to be mature or a risk is perceived that performance may be lower than expected - risk premiums and depreciation are not adequately included in the model. Early investors may be sceptical about the prospects of a technology and demand a premium on return in order to cover the risks of the investment (CE Delft et al, 2009). When commissioning newbuilds if depreciation is faster than expected (due to the adoption of technology (diffusion), lower costs due to the learning curve), the solvency of the company may be threatened. So in some cases a ship owner commissioning a new ship would have to compare the risk of having a ship with an innovative design that may depreciate faster than expected with the risk of having a ship with a conventional design but higher operational costs. In such an assessment, the most fuel efficient ship may not always come out best. CE Delft et al, 2009.

Hidden costs (n.b. hidden to the analyst but not the investing company) - the following costs may not have been included:

Life cycle costs - Hidden costs relating to the energy efficient option's life cycle costs including: identification/search costs, project appraisal costs, commissioning costs, disruption/opportunity costs and additional/specific engineering costs.

Transactional costs – Transaction costs and other unobserved cost items may render apparently cost-effective measures costly. Especially smaller ship owners and operators may experience high transaction costs as they cannot spread the costs of e.g. gathering information over a large number of ships (CE Delft, 2009)

Commissioning/disruption costs - Some measures to reduce emissions require retrofits that can only be installed by temporarily suspending production. These measures are very costly to implement except at times when production is halted for other reasons, such as major maintenance of installations. There may therefore be a lag between the time when a measure becomes available and its actual implementation. Retrofits to existing ships such as the installation of wind power, stern flaps, waste heat recovery systems et cetera can only be done cost-effectively when a ship undergoes a major overhaul. This causes a time-lag of several years in the implementation of cost-effective measures.

If we could accurately represent all the above data/method modifications in a model and still show existence of apparent cost-negative options that were not being employed, we could then draw the conclusion that additional implementation barriers existed. One could then say that there is a gap between the potential reduction achievable and current state, defined as the energy efficiency gap. A barrier may be defined as a postulated mechanism that inhibits investments in technologies that are both energy efficient and economically efficient (cost-negative) (Sorrell et al., 2004). Implementation barriers can be divided into three broad categories – Economic (market barriers & market failures), Behavoiural and Organisational. The focus of this paper is on economic barriers that are inhibiting the uptake of cost-negative measures in shipping.

<u>What remaining implementation barriers may there be?:</u>

Access and costs of capital - Restricted access to capital markets is often considered to be an important barrier to investing in energy efficiency. That is, investments may not be profitable because companies face a high price for capital. As a result, only investments yielding an expected return that exceeds this (high) hurdle rate will be realised (Schleich & Grubber, 2008). Capital rationing is often used within firms as an allocation means for investments, leading to hurdle rates that are much higher than the cost of capital, especially for small projects (Ross, 1986). This leads to competition between projects within a company and may lead to low priority given to energy efficiency. If improving energy efficiency comes at the cost of forgoing other more cost-effective opportunities (because of capital or labour constraints or because the projects are mutually exclusive alternatives), it would be rational for the firm to give energy efficiency a low priority (CE Delft, 2009).

Principal-Agent problems - PA problems refer to the potential difficulties that arise when two parties engaged in a contract have different goals and different levels of information (IEA, 2007). One example is misplaced or split incentives which occur when the costs and benefits of energy efficiency accrue to different agents (Blumstein, 1980, Fisher & Rothkopf, 1989, Howarth & Winslow 1994). In shipping, split incentives are likely to occur due to the different types of charter (and the divided responsibility for fuel costs) existing between shipowners and charterers. For further explanation of this refer to Rehmatulla (2011). Ship owners who invest in fuel efficiency improving measures cannot, in general, recoup their investment, unless they operate their own ships or have long term agreements with charterers currently, because neither charter rates nor second hand prices of ships reflect the economic benefit of its fuel efficiency (CE Delft, 2009, 2011). Charter markets not representing fuel efficiency could be due to the variability of actual fuel use, it is risky for the ship owner to guarantee a low fuel use and hence the fuel efficiency is not reflected in the charter market (IMarEST, 2010). Similarly in time charter contracts speed may be understated and fuel consumption per day may be overstated (Veenstra & Dalen, 2008)

Information problems - Accurate information may be difficult to obtain; those who have information have strategic reasons to manipulate it in order to inflate its value. Sellers advertise and promote their goods by providing information about their own goods. Self-interest is an incentive for the provision of misinformation by sellers, and the costs of acquiring additional information may be high enough to inhibit acquisition of sufficient unbiased information to overcome well-distributed misinformation. Even when provided with information (via labeling) establishing the cost effectiveness of such purchases, is that consumers are wary and mistrustful because of past experience with advertised misinformation (Stern and Aronson 1984). EEDI and other indicators of fuel efficiency thus may not increase the transparency in the market and owners of efficient ships may not be able to command higher charter rates (CE Delft, 2011). One party may have relevant information on the costs and benefits of an energy efficiency investment, but may find this difficult to convey to the other party (Jaffe & Stavins, 1994 p805). If there were no informational problems, the parties would be able to enter into contracts to share the costs and benefits of the investment. However sometimes this may be outweighed by the transaction costs involved hence investment is likely to be forgone despite potential advantages to both parties (Sorrell et al, 2004). A solution to this would be to create a cookie cutter (CCW, 2011) approach of standardising contracts. The information created by the adoption of a new technology by a given firm also has the characteristics of a public good. To the extent that this information is known by competitors, the risk associated with the subsequent adoption of this same technology may be reduced, yet the value inherent in this reduced risk cannot be captured by its creator (Golove & Eto, 1996)

Behavioural barriers for example:

Bounded rationality - Instead of being based on perfect information, decisions are made by rule of thumb Stern & Aronson, 1984.

Inertia In short, inertia means that individuals and organizations are, in part, creatures of habit and established routines, which may make it difficult to create changes to such behaviours and habits. This is stated as an explanatory variable to the "gap" . People work to reduce uncertainty and change in their environments, and avoid or ignore problems (Stern and Aronson, 1984).

Values Values such as helping others, concern for the environment and a moral commitment to use energy more efficiently are influencing individuals and groups of individuals to adopt energy efficiency measures. Thollander et al (2010)

Credibility and trust Another factor that may inhibit adoption is the receiver' s perceived credibility of and trust in the information provider. Energy users cannot always easily gain accurate information about the ultimate comparative cost of different investment options; they will rely on the most credible available information.